UNIVERSITI PUTRA MALAYSIA

# IMPROVED PATH LOSS MODELS FOR RADIOWAVE PROPAGATION IN SUBURBAN ENVIRONMENT IN THE UNIVERSITI PUTRA MALAYSIA CAMPUS AND TAMAN SRI SERDANG

AB. RAZAK BIN MANSOR.

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**By**

**AB. RAZAK BIN MANSOR**


**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science**

**July 2005**

To my parents, to my wife and to my daughters

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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**July 2005**


**Chairman : Zulkifly bin Abbas, PhD**

**Faculty : Science**



This thesis describes the development of a new path loss prediction model called $L_{P4}$ and an improved COST231-Walfisch-Ikegami (ICWI) model in suburban environment in Universiti Putra Malaysia campus and Taman Sri Serdang. The measurements were performed in line-of-sight propagation (for open terrain) and non-line-of propagation (for vicinity of building). The measurement system consists of a spectrum analyzer and a log-periodic antenna. The measured path losses have been compared with various propagation prediction models and results show that these entire models were not in good agreement with the measured path losses. The accuracies of the $L_{P4}$ and ICWI models were found to be within $(3.00 \pm 0.26)\%$ of relative mean error for all measurement frequencies. A computer program FEPL integrating both models was developed using

Agilent VEE . The FEPL program provides the utility for calculating the signal characteristics of radio propagation paths and is realized in the run time version. This program offers path loss results for both open terrain path loss (OTPL) and building environment path loss (BEPL).

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains


**PENAMBAHBAIKAN MODEL KEHILANGAN LALUAN BAGI PERAMBATAN ISYARAT GELOMBANG RADIO DALAM KAWASAN PINGGIR BANDAR DI UNIVERSITI PUTRA MALAYSIA DAN TAMAN SRI SERDANG**

Oleh

**AB. RAZAK BIN MANSOR**

**Julai 2005**

**Pengerusi : Zulkifly bin Abbas, PhD**

**Fakulti : Sains**

Tesis ini memperihalkan pembangunan satu model ramalan kehilangan laluan yang baru dinamakan $L_{P4}$ dan model penambahbaikan untuk CWI di kawasan pinggir bandar Universiti Putra Malaysia dan Taman Sri Serdang. Pengukuran telah dijalankan di laluan tanpa halangan untuk kawasan terbuka dan laluan berhalangan untuk kawasan dikelilingi bangunan. Sistem pengukuran ini terdiri daripada penganalisis spektrum dan antena log-periodic. Nilai kehilangan laluan yang diukur telah dibanding dengan pelbagai model kehilangan laluan, keputusan yang diperolehi menunjukkan bahawa kesemua model ini tidak sesuai bila dibandingkan dengan nilai kehilangan lintasan yang diukur. Ketepatan $L_{P4}$ dan model penambahbaikan bagi COST231-WI didapati berada diantara $(3.00 \pm 0.26)\%$ peratus ralat min relatif bagi semua frekuensi pengukuran. Satu program komputer menggunakan perisian Agilent VEE telah dibina bagi menggabungkan kedua-

dua model tersebut dan diberi nama FEPL model. Program ini dibuat dalam bentuk 'run-time' bagi memudahkan pengiraan ciri isyarat bagi pancaran laluan radio. Program ini menyediakan proses pengiraan kehilangan laluan untuk keadaan kawasan terbuka (OTPL) dan keadaan kawasan di kelilingi bangunan (BEPL).

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I certify that an Examination Committee met on 8th July 2005 to conduct the final examination of Ab. Razak Mansor on his Master of Science thesis entitled "Improved Path Loss Models for Radiowave Propagation in Suburban Environment in the Universiti Putra Malaysia Campus and Taman Sri Serdang" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

**JUMIAH HASSAN, PhD**
Lecturer
Faculty of Science
Universiti Putra Malaysia
(Chairman)

**AZMI ZAKARIA, PhD**
Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

**NOORHANA YAHYA, PhD**
Lecturer
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

**MAZLINA HJ. ESA, PhD**
Associate Professor
Faculty of Electrical Engineering
Universiti Teknologi Malaysia
(External Examiner)

**GULAM RUSUL RAHMAT ALI, PhD**
Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 25 OCT 2005

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master Science. The members of the Supervisory Committee are as follows:

**ZULKIFLY B. ABBAS, PhD**
Lecturer
Faculty of Science
Universiti Putra Malaysia
(Chairman)

**MOHD YUSOF B. SULAIMAN, PhD**
Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

**AINI IDERIS, PhD**
Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 17 NOV 2005

## DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that is has not been previously or concurrently submitted for any other degree at UPM or other institutions.

**AB. RAZAK B. MANSOR**

Date: 6/9/05

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# LIST OF SYMBOLS

| | | |
|---|---|---|
| $P_r$ | - | Received signal power |
| $P_t$ | - | Base station transmit power |
| $h_b$ | - | Base station antenna height |
| $h_m$ | - | Receiver antenna height |
| $h_o$ | - | Building height |
| $r_e$ | - | Effective earth radius |
| $d$ | - | Distance between base station and receiver |
| $b$ | - | Building spacing |
| $L$ | - | Path loss |
| $f/f_c$ | - | Carrier frequency |
| $\vec{E}$ | - | Electric field strength vector |
| $\vec{H}$ | - | Magnetic field strength vector |
| $\vec{B}$ | - | Magnetic flux vector |
| $\vec{D}$ | - | Electric flux vector |
| $\vec{J}$ | - | Electric current density vector |
| $\rho_q$ | - | Charge density |
| $\omega$ | - | Omega |
| $\varepsilon$ | - | Permittivity of medium |
| $\sigma$ | - | Permeability of medium |
| $\mu$ | - | Conductivity of medium |
| $P_{rad}$ | - | Radiated power |
| $G_t$ | - | Transmitter antenna gain |
| $G_r$ | - | Receiver antenna gain |
| $\lambda$ | - | Wavelength of the carrier frequency |
| $L_{FSL}$ | - | Free space loss |
| $R_c$ | - | Reflection coefficient |
| $\Delta\phi$ | - | Phase difference between the direct and ground reflected wave |
| $L_{PEL}$ | - | Plane earth loss |

| | | |
|---|---|---|
| $C$ | - | Rayleigh criterion |
| $\sigma$ | - | Standard deviation of surface |
| $\theta$ | - | Grazing angle |
| $P(x)$ | - | Distribution function |
| $Pdf$ | - | Probability density function |
| $M_R$ | - | Mean of received signal |
| $\sigma$ | - | Standard deviation of received signal $R$ |
| $X$ | - | Zero mean Gaussian distribution |
| $L_{OH}$ | - | Total loss for Okumura Hata Model |
| $L_{CH}$ | - | Total loss for COST231 Hata Model |
| $L_{WI}$ | - | Total loss for Walfisch Ikegami Model |
| $L_{CWI}$ | - | Total loss for COST231 Walfisch Ikegami Model |
| $L_{WB}$ | - | Total loss for Walfisch Bertoni Model |
| $L_{Mi}$ | - | Total loss for measured data point |
| $L_{Pi}$ | - | Total loss for predicted data point |
| $N$ | - | Number of measured data |
| $F$ | - | Objective function |
| $L_{IWI}$ | - | Total loss for improved Walfisch- Ikegami Model |
| $L_{IPEL}$ | - | Total loss for improved Plane Earth Loss Model |
| $L_{ICWI}$ | - | Total loss for improved COST231 Walfisch-Ikegami Model |
| $L_{IWB}$ | - | Total loss for improved Walfisch- Bertoni Model |
| $L_{IOH}$ | - | Total loss for improved Okumura Hata Model |
| $L_{ICH}$ | - | Total loss for improved COST231-Hata Model |

## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| MS | - | Mobile Station |
| BSS | - | Base Station Subsystem |
| MSC | - | Mobile Switching Centre |
| PSTN | - | Public Switched Telephone Network |
| HLR | - | Home Location Register |
| BTS | - | Base Transceiver Station |
| AI | - | Air Interface |
| RF | - | Radio Frequency |
| LOS | - | Line Of Sight |
| NLOS | - | None Line Of Sight |
| VEE | - | Agilent environment engineering |
| EM | - | Electromagnetic |
| COST231 | - | European Cooperation in the field of Scientific and Technical Research |
| GPS | - | Global Positioning System |
| PC | - | Computer |
| amsl | - | Above mean sea level |
| EOL | - | End on line |
| DAQ | - | Data acquisition |
| BTS | - | Base Station Transmitter |
| RME | - | Relative Mean Error |
| CWI | - | COST231 Walfisch-Ikegami model |
| WB | - | Walfisch-Bertoni model |
| OH | - | Okumura-Hata model |
| CH | - | COST231-Hata model |
| EB | - | Engineering Building |
| ERCB | - | Eleventh Residential College Building |
| FEPL | - | Faculty Engineering Path Loss |
| GTD | - | Geometrical Theory of Diffraction |
| UTD | - | Uniform Theory of Diffraction |

# CHAPTER 1

# INTRODUCTION

## 1.1 Historical Overview

The ability to communicate with people on the move has evolved remarkably since Guglielmo Marconi first demonstrated radio's ability to provide continuous contact with ships sailing through the English channel. That was in 1897, and since then new wireless communications methods and services have been enthusiastically adopted by people throughout the world. Now, the cellular mobile communications industry has recently been one of the fastest-growing industries of all time, with the number of users increasing rapidly. It has been reported that a new wireless subscriber signs up every 2.5 seconds (Chandran, 2002). Today, with the advent of radio technology, cellular communication has reached all walks of life, bringing communities and business closer than ever before. It enables us to communicate with anyone at any time from anywhere within the service area.

The origin of radio can be traced back to the year 1680 to Newton's theory of composition of white light. He postulated that white light was a composition of various colors. This theory brought the importance as light as an area of study to the attention of many scientists who began to pursue experiments with light. Some important discoveries connected to the eventual development of the radio are present here. In 1873, James Clerks Maxwell united all the w wn laws of electrostatics, magneto-static, and electrodynamics, as a result of work of Poisson (in electrostatics), Gauss (in magneto static), Ampere (in electrodynamics), and Faraday (in magneto-dynamics), in a unified theory of electromagnetism. He described these laws in a completed form of four coupling equations (Maxwell's Equation).

Fifteen years later, in 1888, Heinrich Rudolf Hertz demonstrated practically the phenomena which Maxwell had obtained mathematically. Hertz's showed that electromagnetic wave propagation was possible in free space and hence demonstrated of radio communication. In 1892, less than five years later, a paper written by the British scientist Sir William Crookes predicted that telegraphic communication over long distances was possible using tuned receiving and transmitting apparatus and this early work was soon turned into the first practical communication system by the entrepreneur Gugliemo Marconi ( Marconi Co. Ltd., 1981), where he established a radio link over a distance of a few miles in 1895. With this experiment, it brought a revolution to the mobile radio industry.

During the mid-1930s, two way radio communication links were designed at frequencies of 30 to 40 MHz. A decade later, broadcasting system using mobile communication channels were operated at frequencies of 100 to 200 MHz. In 1960s, the first World Administration Radio conference (WARC, now the WRC) was held and recommendations were issued regarding the assignment of radio frequency band (Lee,1989). After that, the designers of communications system started employ the frequency band up to 450 MHz. From 1930 to 1960, the range of frequencies brought into service for radio communication gradually increased to include the metric , decimetric and centimetric wavelengths. Then, the frequency modulation was used.

In the 1970s, the analog cellular systems were developed by Bell Laboratories (Rappaport, 2002) where it brought a deeper effect to the radio industry. In 1979, the first cellular system, called Advanced Mobile Phone Service ( AMPS) was installed in Chicago, followed in 1980 by the High Capacity Mobile Telephone System (HCMTS) in Tokyo. During the 1981s, the Nordic Mobile Telephone (NMT) was introduced in Scandinavia. In 1985, France's Radiocom 2000 became operational, as did the United Kingdom's TACS and Germany's C 450 systems (Tabbane, 2000).

At the beginning of the 1990s, mass-produced, low cost cordless system reached impressive growth rates. Among these, cellular was one in which its share in this growth process was by far the most important, especially since the advent of international digital standards such as Global of System for Mobile Communications (GSM) and CDMA system (IS-95) (Prasad, 1998; Woodward, 1998). The cellular systems in operation at present are divided into two categories: the first-generation analog systems and the second generation digital systems.

Today, one can observe the fast growth of various types of wireless communication systems, such as personal fixed and mobile, land and satellite, which use a wide frequency band from 500 MHz up to 3 to 10GHz. In 2002, the IMT-2000 third generation cellular mobile system was developed where it relies on cellular techniques and reuses the basic concepts of architecture, functionality and services of these systems (Fujimoto, 2001).

## 1.2 Cellular Radio Concept

Today's wireless communication systems are based on a composite wireless and wired system as shown in Figure 1.1. Figure 1.1 shows a basic cellular system which consists of mobile stations (MS), base station subsystem (BSS) and mobile switching centre (MSC). Mobile switching centre (MSC), often simply called the switch is the central hub of the network. It provides connection between the cellular network and the public switched telephone network (PSTN) and also between cellular subscribers. Details of the subscribers for whom this network is the home network are held on a database called the home location register (HLR), while the details of subscribers who have entered the network from elsewhere are on the visitor location register (VLR). These details include authentication and billing details, plus the current location and status of the subscriber.

The base station subsystem (BSS) is composed of a base station controller (BSC) which handles the logical functionality, plus one or several base transceiver stations (BTS) which contain the actual RF and baseband parts of the BSS. The BTSs communicate over the air interface (AI) with the mobile stations (MS). The air interface includes all of the channel effects as well as the modulation, demodulation and channel allocation procedures within the MS and BTS.